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DESIGN OF THE VAPOR DIFFUSION CHARACTERISTICS OF THE EXTERIOR FACING OF THE FAÇADE THERMAL INSULATION SYSTEMS

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Abstract. *Various facade facings – systems made of thermal insulation materials with the finishing facade renders which are directly applied to the facade walls are simple for construction and are applied in the newly built structures, and they are also suitable for the application in the cases of the energy revitalization of the existing buildings.*
The exterior walls, and especially their outer layers, are exposed to various atmospheric influences. They cause different effects in the walls, one of them being the occurrence of the water vapor condensation. In the walls with the facade thermal insulation systems, the occurrence of the water vapor condensation may be caused by the vapor diffusion characteristics of the exterior render. At certain temperatures and humidity of the external and internal air, there are several conditions for the occurrence of the water vapor condensation in the wall with the facade thermal insulation system, when the exterior render is of higher relative resistance to the water vapor diffusion.
Therefore, it is useful to determine the vapor diffusion characteristics, that is, highest values of the relative resistance to the water vapor diffusion of the exterior renders which will not cause the condensation of the water vapor in the wall, or at least those that will not cause the impermissible dampening of the wall material, and will allow for the possibility of moisture drying.

1. INTRODUCTION

It is well known that there is a number of different façade facings – systems of thermal insulation materials which are directly applied to the exterior walls, with finishing façade renders.

Such systems are simple for construction and they are applied in the newly built structures, and they are also suitable for the application in the cases of the energy revitalization of the existing buildings.

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The quality of the thermal insulation façade facings and their energy efficiency are directly dependable on the characteristics of the components, as well as of the usage conditions. The application of the certain components of the different patented systems, in the conditions where the quality of the system is not guaranteed, the significant damage in the exploitation may occur. By the determination of the possible consequences of the influences to the system, the conditions of the application where no damage will occur may be established. For this purpose, the Development project in the framework of the National program of energy efficiency – Development of the façade thermal insulation system, financed by the Ministry of Science, Technology and Development (now Ministry of Science and Environment protection) of the Government of the Republic of Serbia, is being realized at the Faculty of Civil Engineering and Architecture of Nis.

The exterior walls of the buildings, and especially the external layers of those walls are exposed to various internal and atmospheric influences. They often act simultaneously upon the buildings, so it is difficult to determine which the dominant one is. The complex and variable influences cause different processes in the walls, one of them being the condensation of the water vapor in or on the walls, and the consequences of those processes are the building damage. Thus, the effects of the dampness condensation in walls are: reduction of the heat insulating capability of the material, corrosion or decay of the material, their destruction etc.

It is obvious that it is required to prevent the said harmful effects of the water vapor condensation through the design and construction of the appropriate structure of the walls with the façade thermal insulation systems.

2. CONDENSATION OF WATER VAPOR IN THE WALLS WITH THE FAÇADE THERMAL INSULATION SYSTEM

The façade composite systems are applied on the external side of the façade walls, and apart from the thermal insulation layer, they must contain the layers of different materials for various purposes, as displayed on the figure 2.1.

The protective external layers may be the mortars on the basis of artificial or silicon resins, then the mineral renders with the reinforcement mash, as well as the ceramic elements, figure 2.2.

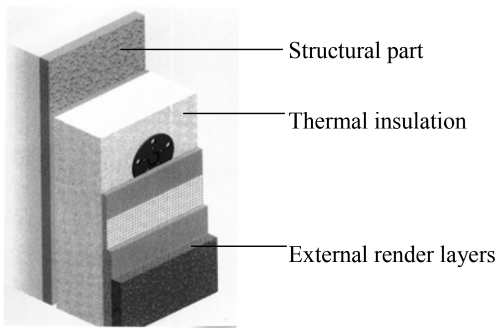

Fig. 2.1. Structure of the façade thermal insulation systems

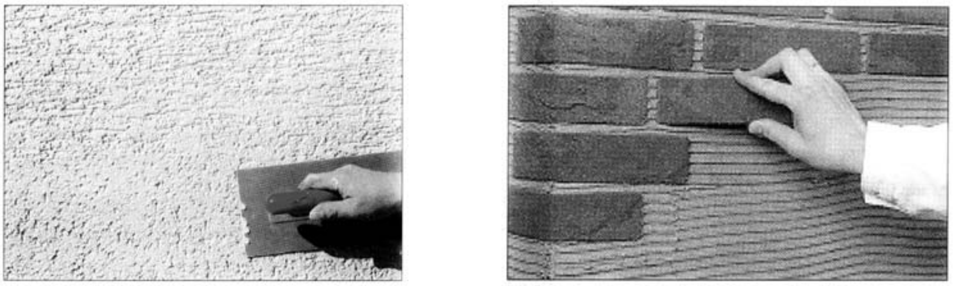

Fig. 2.2. Finishing, decorative layers of the façade thermal insulation systems

In general, the occurrence of water vapor condensation within the wall depends on:
- the temperature and the humidity of the interior and the exterior air
- structure of the wall.

In certain walls and at certain temperatures and interior and exterior air humidity, the occurrence of the internal water vapor condensation is the consequence of the sequence of the wall materials. It will not occur, when the layers of material are placed in such a manner that their heat resistance increases, while the diffusion resistance decreases, regarded from the interior towards the exterior side of the wall[1], and it is considered that the humidity will not cause damage if it is not higher than a certain amount, depending on the type of material being moistened, and if it dries up in the period when the conditions for drying are propitious.

Namely, according to the national regulations (6) the partitions in the building should be designed and constructed in such a manner that for the predicted regime of usage:

- There may not occur the water vapor condensation, which, by the diffusion penetrates the partition, or
- The total quantity of water vapor at the end of moistening period, cannot effect building damage.

In case the water vapor is condensed within the partition, the following conditions must be fulfilled:

- The total dampness of the material $\mathbf{X_{uk}'}$ in which the water vapor condensed is less than the highest permissible dampness $\mathbf{X_{max}'}$**;** the values can be determined on the basis of the appropriate standards.
- That the dampness caused by the condensation may be dried up in the period when the conditions for drying are favorable, that is, if the required number of days **Z** for drying is less than the number of days $\mathbf{Z_{max}}$ set by the standard.

At the walls with the façade thermal insulation system in the specific conditions, the occurrence of the water vapor is most frequently the consequence of the influence of the vapor diffusion characteristics of the external renders. On the basis of the diffusion diagram in the figure 3.4, wall in the figure 2.3 in the same conditions and with the external renders of the different relative resistance of the water vapor diffusion, one may

[1] Bogdanović V.: Architectural and building construction-Thermal protection of the buildings, The Faculty of Civil Engeneering and Architecture of Niš, Niš, 2000.

observe that there are several conditions for the occurrence of the water vapor diffusion in the wall with the higher relative resistance to the water vapor diffusion.

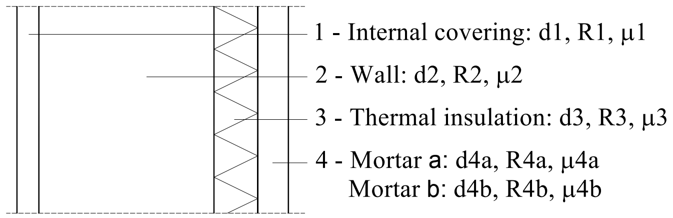

Fig. 2.3. Exterior wall with the façade insulation system

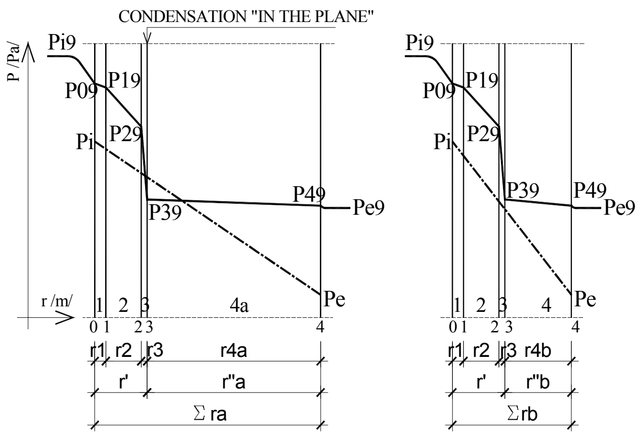

Fig. 2.4. Diffusion Diagram

Considering the fact that their purpose is the protection of the thermal insulation and the partitions from the atmospheric influences, it is necessary to have the external renders sufficiently water impermeable, but sufficiently vapor permeable. Therefore, it is best to apply those renders that will not cause the condensation of the water vapor in the wall, or at least those that will not cause the impermissible dampening of the wall material, with the possibility of drying up.

2.1 Condition that there is no condensation of the water vapor in the walls

As a rule at the walls with the façade thermal insulation systems, the decrease of the temperature is considerably higher through the thermal insulation layer, than through the other layers. On the basis of the graphic and analytic method, by the application of the diffusion diagram, and the drop of the saturation pressure through the said layer will be significantly higher. If the relative resistance of the water vapor diffusion of the heat insulation layer is relatively small, such as the rock wool, it may be considered that there may occur the water vapor condensation "in the plane" (6), in the heat insulation layer, as in the 2.5. As the conditions for the occurrence of the water vapor condensation, the intersecting of the partial pressure line P and the saturation pressure line P', depend on the relative resistance of the external render to the water vapor diffusion, that means that its value may be determined, and so the water vapor condensation will not occur.

In case of the known temperatures and the humidity of the interior and exterior air t_i, t_e, φ_i, φ_e, on the basis of the diffusion diagram in the figure 2.5., on may conclude that, in the wall, there will not occur the condensation of the water vapor if the value of the saturation pressure $P_k'=P_3'$ is higher than the value of the partial pressure $P_j=P_3$ at the border of 3rd and 4th layer. The heat resistance of the exterior render is ignored as the relatively small value.

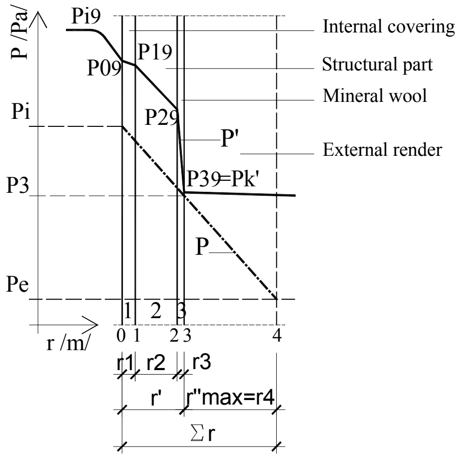

Fig. 2.5. Diffusion diagram

In the previous figure, the markings have the following meaning:

- P' – line of saturation pressures,
- P – line of partial pressures,
- P_i and P_e – partial pressures of the water vapor of the internal and external air of the temperatures t_i and t_e,
- r' – sum of the relative resistances to the water vapor diffusion of the layers from the internal side of the wall to the lowest point Pk' of the saturation pressures line P',
- r''_{max} – highest vale of the relative resistance to the water vapor diffusion of the external render.

Therefore, on the basis of the diagram in the figure 2.5 and with the following conditions

$$P_3 \langle Pk', \ /Pa/ \qquad (2.1.1)$$

the highest value of the relative resistance to the water vapor diffusion r_{max}'' of the external render, when there is no condensation of the water vapor in the mineral wool, is:

$$r_{max}'' < \frac{r' \cdot (Pk' - Pe)}{Pi - Pk'} . \quad /m/ \tag{2.1.2}$$

The highest value of the resistance to the water vapor diffusion factor μ_{max} (6) of the external render thickness d /m/, when there is no water vapor condensation in the mineral wool, is:

$$\mu_{max} = \frac{r_{max}''}{d} . \tag{2.1.3}$$

In the following example, there is the practical application of the previously derived expressions for determination of the external render characteristics, so that in the observed wall there is no water vapor condensation.

The wall is in the 1st climatic zone, with the following characteristics of the interior air:

The air temperature is t_i = 20ºC and the relative humidity is φ_i = 60%.

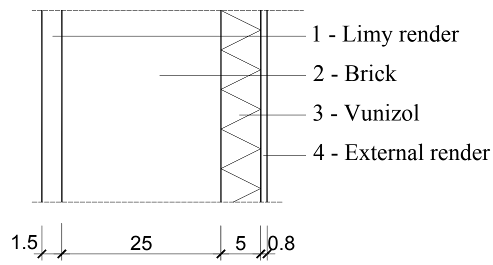

Fig. 2.6. An example of the wall with the façade thermal insulation system

The exterior wall characteristics: t_e = 5ºC i φ_e = 90% for the requirements of the analysis of the water vapor diffusion in the winter season are taken from the national standards (6) as well as the heat resistances: Ri = 0,13 m^2K/W i Re=0,04 m^2K/W .

Table of data for the diffusion diagram

bo. la.	Layer	d m	r $\frac{kg}{m^3}$	λ $\frac{W}{mK}$	μ	R $\frac{m^2K}{W}$	Δt ºC	t ºC	P' Pa	P Pa	r m
1	2	3	4	5	6	7	8	9	10	11	12
i	Inside					0,13		20	2335	1401	
0							1,1	18,9	2178	1401	
1	Limer ender	0,015	1600	0,81	10	0,0185	0,2	18,7	2157		0,15
2	Brick	0,25	1800	0,76	12	0,329	2,8	15,9	1802		3
3	Vunizol	0,05	100	0,041	1	1,22	10,5	5,4	832		0,05
4	Render	0,008			**?**						**?**
e	Outside					0,04	0,4	5	813	731,7	

By the application of the expression (2.1.2), the following formulae is obtained

$$r_{max} = r_4 \langle \frac{3,2 \cdot (832 - 731,7)}{1401 - 832} \quad \text{and} \quad r_{max}'' = r_4 < 0,564 \text{ m}.$$

The diffusion diagram in the figure 2.7 is drawn with the value $r_4 = 0,56$ m, and it is observable that $P_3 < P_3'$, meaning there is no water vapor condensation in the wall.

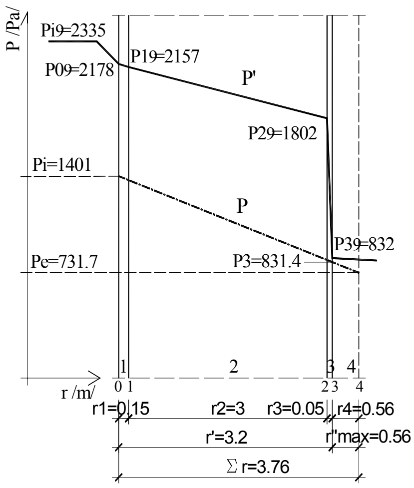

Fig. 2.7. Diffusion diagram

The resistance factor to the water vapor diffusion of the exterior render 8 mm thick, so that there is no water vapor condensation in the wall, is:

$$\mu_{max} = \mu_4 = \frac{0,56}{0.008} = 70.$$

4. CONCLUSION

The significance of the water vapor characteristics of the water vapor characteristics of the external render of the façade thermal insulation systems can be seen in their influence to the occurrence of the condensation in some of the wall layers, and at the systems with the rock wool, in the wool itself. As their purpose is the protection of the thermal insulation and the partitions themselves from the atmospheric conditions, it is required that the external renders are sufficiently water impermeable, but sufficiently water vapor permeable. For these reasons, it is more favorable to have the relative resistance to the water vapor diffusion as low as possible, which in case of the certain thickness, also conditions as small the factor of the water vapor diffusion resistance as possible.

The possibility of the analytic design of the water vapor characteristics of the external render contributes to the application of the façade thermal insulation systems where no water vapor condensation will occur, or at least of those where there will be no impermissible moistening of the wall material, with the possibility of drying up, so as to prevent the building damage from the condensed moisture.

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PROJEKTOVANJE PARODIFUZNIH KARAKTERISTIKA SPOLJAŠNJIH OBLOGA FASADNIH TERMOIZOLACIONIH SISTEMA

Veliborka Bogdanović, Danijela Milanović

Različite fasadne obloge-sistemi od termoizolacionih materijala sa završnim fasadnim malterima, koji se direktno apliciraju na fasadne zidove, su jednostavni za izvođenje i primenjuju se kod novogradnji, a takođe su pogodni za primenu kod energetskih revitalizacija postojećih zgrada.

Spoljašnji zidovi, a posebno njhovi spoljašnji slojevi, izloženi su različitim atmosferskim uticajima. Oni uslovljavaju različite pojave u zidovima, od kojih je jedna kondenzacija vodene pare. Kod zidova sa fasadnim termoizolacionim sistemima, pojava kondenzacije vodene pare može biti uslovljena parodifuznim karakteristikama spoljašnjih maltera. Pri određenim temperaturama i vlažnostima spoljašnjeg i unutrašnjeg vazduha, više uslova za nastajanje kondenzacije vodene pare ima u zidu sa fasadnim termoizolacionim sistemom kada je spoljašnji malter većeg relativnog otpora difuziji vodene pare.

Stoga je od interesa odrediti parodifuzne karakteristike, odnosno, najveće vrednosti relativnih otpora difuziji vodene pare spoljašnjih maltera koji neće uslovljavati kondenzaciju vodene pare u zidu, ili makar one koji neće uslovljavati nedozvoljeno vlaženje materijala zida uz mogućnost isušenja vlage.